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SHEATHED-ELEMENT GLOW PLUG HAVING AN IONIC CURRENT SENSOR AND METHOD FOR OPERATING SUCH A SHEATHED-ELEMENT GLOW PLUG

Background Information

The present invention is based on a ceramic sheathed-element glow plug for diesel engines having an ionic-current sensor according to the species defined in the first independent claim. The German laid open print 34 28 371 has already described ceramic sheathed-element glow plugs which have a ceramic heating element. The ceramic heating element bears an electrode made of a metallic material which is used to determine the electric conductivity of the ionized gas present in the combustion chamber of the internal-combustion engine. In this case, the combustion chamber wall is used as the second electrode.

Furthermore, sheathed-element glow plugs are known which have a housing in which a rod-shaped heating element is disposed in a concentric bore hole. The heating element is made of at least one insulating layer, as well as a first and a second lead layer, the first and the second lead layers being connected via a bar at the tip of the heating element on the combustion chamber side. The insulating layer is made of electrically insulating ceramic material, and the first and second lead layers, as well as the bar are made of electroconductive ceramic material..

Summary of the Invention

The ceramic sheathed-element glow plug of the present invention with ionic-current sensor, having the features

of the first independent claim, has the advantage that the sheathed-element glow plug with ionic-current sensor has a very simple design and is inexpensive to manufacture.

The measures specified in the dependent claims permit advantageous further developments and improvements of the sheathed-element glow plug with ionic-current sensor indicated in the main claim. It is possible to achieve a particularly advantageous design of a sheathed-element glow plug if the glow operation and the ionic-current measurement can be carried out simultaneously. It is also advantageous to lead the electrode for detecting ionic current up to the end of the heating element on the combustion chamber side, since the ionic current may thus be detected in a region of the combustion chamber which is significant for the combustion processes taking place in the combustion chamber. It is also advantageous to design two electrodes for detecting ionic current in such a way that the ionic current flows from the one electrode to the other electrode, and thus only crosses a region of special interest for the ionic-current measurement. It is likewise advantageous to use the ceramic composite structure described below for the various heating-element layers, whose conductivity and expansion coefficient can be adapted very well. This holds true equally for the precursor composites described below.

In the method for operating a sheathed-element glow plug having ionic-current measurement, it is particularly advantageous to provide the ionic-current detection during the glowing of the heating element, since it is of interest to detect the combustion process during the start phase of the internal combustion engine, as well.

Further advantages come to light from the following description of the exemplary embodiments.

Brief Description of the Drawing

Exemplary embodiments of the invention are shown in the drawings and are explained in greater detail in the following description.

Figure 1 shows schematically in a longitudinal section, a sheathed-element glow plug of the present invention with ionic-current sensor;

Figure 2 shows a schematic longitudinal section through the combustion-chamber-side end of a sheathed-element glow plug of the present invention with ionic-current sensor;

Figures 3a and b each show a schematic longitudinal section through the heating element of a sheathed-element glow plug of the present invention with ionic-current sensor; and

Figure 4 shows a schematic cross-section through a heating element of a sheathed-element glow plug of the present invention with ionic-current sensor.

Description of the Exemplary Embodiments

Figure 1 shows a sheathed-element glow plug of the present invention schematically in longitudinal section. A tubular, preferably metallic housing 3 contains a heating element 5 in its concentric bore hole at the end on the combustion chamber side. Heating element 5 is made of ceramic material. Heating element 5 has a first lead layer 7 and a second lead layer 9, first lead layer 7 and second lead layer 9 being made of electroconductive ceramic material. At end 6 of heating element 3 remote from the combustion chamber, first lead layer 7 and second lead layer 9 are connected by a bar 8 likewise made of electroconductive ceramic material. First lead

layer 7 and second lead layer 9 are separated from each other by an insulating layer 11. Insulating layer 11 is made of electrically insulating ceramic material. The interior of housing 3 is sealed in the direction of the combustion chamber by a combustion-chamber seal 13 surrounding heating element 5 in a ring shape. At the end of heating element 5 remote from the combustion chamber, first lead layer 7 is connected to a third connection 37. In the direction of the end of the sheathed-element glow plug remote from the combustion chamber, this third connection 37 is in turn connected to terminal stud 19. At its end remote from the combustion chamber, second lead layer 9 has a contact area 12 via which second lead layer 9 is electrically connected to housing 3 by way of electroconductive combustion-chamber seal 13. Housing 3 is connected to ground. In one preferred exemplary embodiment, contact area 12 may be constructed in such a way that in this region, the electrically insulating glass coating surrounding the end of heating element 5 remote from the combustion chamber is interrupted, and consequently an electrical contact is produced with combustion-chamber seal 13. In one particularly preferred exemplary embodiment, contact area 12 is provided with a metallic coating.

Terminal stud 19 is set apart from the end of heating element 5 remote from the combustion chamber by a ceramic spacer sleeve 27 disposed in the concentric bore hole of housing 3. In the direction of the end remote from the combustion chamber, terminal stud 19 is led through a clamping sleeve 29 and a metal sleeve 31. At the end of the sheathed-element glow plug remote from the combustion chamber, a circular connector 25, which effects the electrical connection, is mounted on terminal stud 19. The end of the concentric bore hole of housing 3 remote from the combustion chamber is sealed and electrically insulated by a tubing ring 21 and an insulating disk 23.

The invention is clarified more precisely once again with reference to Figure 2. Only the end of a sheathed-element glow plug according to the present invention on the combustion chamber side is shown schematically in longitudinal section. Compared to Figure 1, heating element 5 is intersected in a plane transverse to the sectional plane of Figure 1. Here, only insulating layer 11 is visible. Running within insulating layer 11 are two electrodes 33 and 33' for detecting ionic current which are broadened at end 6 of heating element 5 on the combustion chamber side. In a further exemplary embodiment, electrodes 33 and 33' may also be applied outside on the insulating layer. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to a first connection 15. Second electrode 33' for detecting ionic current is likewise connected at the end of heating element 5 remote from the combustion chamber to a second connection 17. First connection 15 and second connection 17 are passed through terminal stud 19 to the end of the sheathed-element glow plug remote from the combustion chamber. As already mentioned, first lead layer 7 is connected to terminal stud 19 with the aid of a third connection 37.

The arrangement of the various layers of heating element 5 together with the associated connections are shown again with reference to Figure 3. Figure 3a) shows a heating element 5 in longitudinal section. First electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are disposed in insulating layer 11. At the end of heating element 5 remote from the combustion chamber, first electrode 33 for detecting ionic current is connected to first connection 15, and second electrode 33' for detecting ionic current is connected to second connection 17. In addition, at the end of heating element 5 on the

combustion chamber side, bar 8 is discernible which connects first lead layer 7 and second lead layer 9 to one another.

Figure 3b) shows heating element 5 which is intersected in a plane transverse to the plane in which heating element 5, which was shown in Figure 3a), is intersected. Recognizable here are first lead layer 7 and second lead layer 9 which are interconnected via bar 8 at end 6 of heating element 5 remote from the combustion chamber. Third connection 37 is connected to first lead layer 7 at the end of heating element 5 remote from the combustion chamber.

To better clarify the invention, Figure 4 shows a cross-section through heating element 5 at the end remote from the combustion chamber. It is discernible that first lead layer 7 is separated from second lead layer 9 by insulating layer 11. Arranged within insulating layer 11 is first connection 15 which is connected to first electrode 33 for detecting ionic current. Likewise arranged within insulating layer 11 is second connection 17 which is connected to second electrode 33' for detecting ionic current. Furthermore, third connection 37 is disposed within first lead layer 7. It can be seen that, to better accommodate and insulate first and second electrodes 33, 33' for detecting ionic current, the insulating layer is broadened in the region in which these electrodes are arranged.

In a first exemplary embodiment, the sheathed-element glow plug may be operated in such a way that during the start of the internal combustion engine, the sheathed-element glow plug is initially operated in heating mode. This means that during the glow phase, a positive voltage with respect to ground is applied to third connection 37, so that a current flows across first

lead layer 7, bar 8 and second lead layer 9. Due to the electrical resistance on this path, the temperature of the heating element rises, and the combustion chamber, into which the end of the sheathed-element glow plug on the combustion chamber side extends, is heated. After ending the glow phase, a voltage potential is applied to first connection 15 and second connection 17, so that first electrode 33 and second electrode 33' are used as electrodes for measuring ionic current. If the combustion chamber is ionized due to the presence of ions, then an ionic current can flow from electrodes 33, 33' for detecting ionic current to the combustion-chamber wall which is grounded. In this exemplary embodiment, first electrode 33 for detecting ionic current and the second electrode for detecting ionic current act as electrodes at the same potential in parallel.

In a further exemplary embodiment, it is also possible to apply a different voltage potential to first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current, so that an ionic current flows between first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current.

In another exemplary embodiment, the glow operation and the detection of ionic current may be carried out simultaneously by the sheathed-element glow plug. To that end, in each case the voltage necessary for the glow operation and for detecting ionic current is applied simultaneously to third connection 37 and to first and second connections 15, 17, respectively. In this context, the voltage potentials may be selected such that first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are at the same or different potential, that is to say, as described above, the ionic current flows via the ionized combustion chamber to the combustion chamber wall, or from first

electrode 33 for detecting ionic current via the ionized combustion chamber to second electrode 33' for detecting ionic current.

In a first exemplary embodiment, the materials of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and electrode 33 for detecting ionic current, as well as second electrode 33' for detecting ionic current should be made of ceramic material. This ensures that the thermal expansion coefficients of the materials scarcely differ, thus guaranteeing the endurance strength of heating element 5. In this context, the material of first lead layer 7, bar 8 and second lead layer 9 is selected such that the resistance of these layers is less than the resistance of insulating layer 11. In the same way, the resistance of first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current is less than the resistance of insulating layer 11.

In a further exemplary embodiment, first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current may also be made of metallic material, e.g. platinum.

In one preferred exemplary embodiment, first lead layer 7, bar 8 and second lead layer 9, insulating layer 11 and possibly first electrode 33 and second electrode 33' are made of ceramic composite structures which contain at least two of the compounds AL_20_3, $MoSi_2$, Si_3N_4 and Y_20_3. These composite structures are obtainable by a one-step or multi-step sintering process. The specific resistance of the layers may preferably be determined by the $MoSi_2$ content and/or the grain size of $MoSi_2$; the $MoSi_2$ content of first lead layer 7, of bar 8 and of second lead layer 9, as well as of first and second electrodes 33, 33' for detecting ionic current is preferably higher than the

$MoSi_2$ content of insulating layer 11.

In a further exemplary embodiment, first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and possibly first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are made of a composite precursor ceramic having different portions of fillers. The matrix of this material is made of polysiloxanes, polysesquioxanes, polysilanes or polysilazanes which may be doped with boron, nitrogen or aluminum and are produced by pyrolysis. At least one of the compounds Al_2O_3, $MoSi_2$, SiO_2 and SiC forms the filler for the individual layers. Analogous to the composite structure indicated above, the $MoSi_2$ content and/or the grain size of $MoSi_2$ may preferably determine the resistance of the layers. The $MoSi_2$ content of first lead layer 7, of bar 8 and of second lead layer 9, and possibly of first and second electrodes 33, 33' for detecting ionic current is preferably set higher than the $MoSi_2$ content of insulating layer 11. In the exemplary embodiments indicated above, the compositions of first lead layer 7, bar 8, second lead layer 9, insulating layer 11 and possibly of first electrode 33 for detecting ionic current and second electrode 33' for detecting ionic current are selected such that their thermal expansion coefficients and the shrinkages occurring during the sintering and pyrolysis processes are identical, so that no cracks develop in heating element 5.